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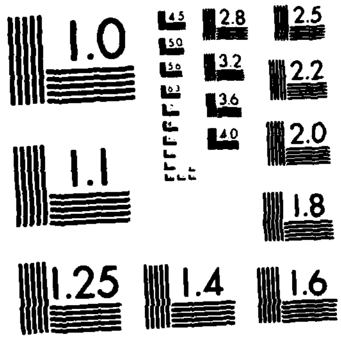

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CRREL's *Cold Regions Technical Digests* are aimed at communicating essential technical information in condensed form to researchers, engineers, technicians, public officials and others. They convey up-to-date knowledge concerning technical problems unique to cold regions. Attention is paid to the degree of detail necessary to meet the needs of the intended audience. References to background information are included for the specialist.

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Solving problems of ice-blocked drainage

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Introduction

Once the processes that lead to ice-blocked drainage facilities are understood (*Ice-Blocked Drainage: Problems and Processes,* Cold Regions Technical Digest No. 83-2), it is possible to work out intelligent solutions to these problems. Many solutions have been developed by local maintenance forces in their own areas. Probably some of these solutions are not familiar to people at the Cold Regions Research and Engineering Laboratory. On the other hand, some of the solutions described in this digest article may not be familiar to many maintenance personnel. The article also contains some new ideas about familiar solutions, all based on CRREL's experiences in the world's cold regions with a wide variety of engineering works and many types of winter conditions.

Solutions to problems of ice-blocked drainage fall into two categories: ice control and ice prevention. Actually a third category also exists—the physical removal of ice after blockage has taken place. But this approach, even though it is often used, is usually not very satisfactory. It is more a case of reacting to problems than of solving them.

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It is not possible to entirely prevent the formation of ice in very many situations. Usually it takes changes in the design of drainage facilities to prevent ice formation, but maintenance forces have to work with designs as they exist. So mainly attention will be focused on ways of controlling ice buildup as part of regular maintenance operations. These techniques may allow ice to form, but will slow down its formation or will maintain an unfrozen opening so that drainage flow can always pass through.

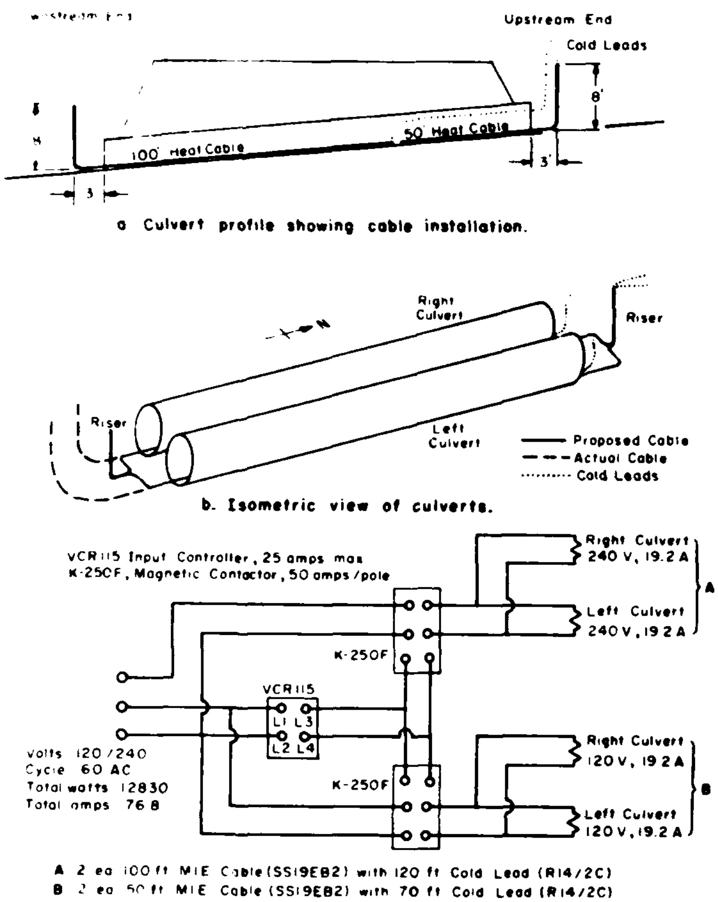
Maintenance solutions

It is important in any approach to ice problems to keep culverts and ditches cleared of trash and debris. This basic requirement removes spots where ice blockage gets started, eliminating several ice problems at the very beginning.

In what follows, maintenance solutions to ice-blockage problems are discussed under the categories of culverts, ditches, etc. But this does not mean that the solutions can only be used for those facilities. If a solution appears applicable in some other way, go ahead and use it. It may take some experimentation, but excellent results could be obtained.

Culverts. Where a problem exists because a culvert fills with ice, and if other conditions are right, it may help to simply block off the culvert temporarily at the upstream end in the fall. This will work where the flow is very small, and where there is enough storage space upstream from the culvert to hold the resulting ice. Successful closures have been made of wood, innertubes, canvas, or sheet plastic. This technique keeps the culvert itself open so that it doesn't have to be thawed in the spring, and it can be ready to handle heavy flow. But the closure has to be removed in the spring, and this may involve chopping or thawing ice at the culvert entrance.

Several ways exist to apply heat to culverts, either to keep them from freezing or to thaw an opening through the ice blockage. The most successful way uses electric heating cables (Figure 1), with the electricity supplied either by local power lines or by temporary connection to truck-mounted generators. These cables are usually of the mineral-insulated type with a copper or stainless steel sheath. Strung through the culvert in the fall and removed in the spring, the cables are turned on when needed. In some cases, they are left on all winter, but this is not efficient and seldom is it needed. In some permanent installations in Alaska the heating cable is



a. Culvert profile showing cable installation.

b. Isometric view of culverts.

c. Wiring diagram.

1. Diagram of a typical electric heating cable installation.

enclosed in a small-diameter steel pipe mounted on the inside culvert wall, one-fifth to one-quarter of the diameter up from the bottom.

The heating cables and voltages usually used give a maximum heat output of 40 to 50 watts per linear foot. However, good results can be obtained with electrical control devices that limit the output to lower levels. For example, for a cable submerged in a completely ice-filled culvert, an output of only 10 watts per linear foot will melt a hole or tunnel in the ice that reaches about 8 inches in diameter in 8 or 9 days if the meltwater is drained away as thawing takes place. But for the greatest efficiency in melting a tunnel in solid ice, the highest available heat cable output should be applied continuously for a short period of time, until the thawed tunnel reaches a

desired size, and then the power should be shut off or reduced to very low levels. In the foregoing example, using 50 watts per linear foot would yield the same 8-in.-diameter tunnel in only about 4.7 hours, with the total expenditure of electrical energy being only about 12% of that used at 10 watts per linear foot.

Steam thawing is familiar to most maintenance personnel. The steam is usually generated in truck-mounted boilers, and applied through hoses connected to portable steam lances. A great improvement in performance and convenience comes from the use of a permanently installed thaw pipe inside a culvert. The thaw pipe is attached by clamps or hangers to the top of the culvert. Placing it along the bottom of the culvert brings the chance of damage from falling ice or waterborne debris. Pipe sizes are ½, ¾ and 1 in. in most cases, but sizes from ³/₈ to 2 in. have also been used. The thaw pipe has a vertical riser at each end of the culvert, high enough to go above any ice or snow. The pipe is filled with an antifreeze solution, and the risers are capped except when steaming is taking place.

During steaming, a steam hose is attached to one of the risers, and a condensate-return hose is connected to the other riser. The antifreeze is collected through the return hose for re-use, and then steam is cycled through the pipe. Anywhere from 30 minutes to an hour is needed to make a hole about 4 in. in diameter, based on the output of ordinary small portable boilers. A thawed opening this size is usually enough to keep flow going through a culvert in the spring, and a larger hole is melted out as flow continues. Perforated thaw pipes do not perform well, because most of the thawing takes place only near the first few perforations, and the condensate can't be saved. Depending on the rate of ice buildup, steam thawing is done at periodic intervals throughout the winter. This will take care of midwinter thaws and rains, but in particular the drainage facilities will be ready for runoff in the spring.

Fuel oil heaters, often called firepots, have been used in Alaska and Canada for years. They are inefficient and costly in both fuel and labor, but for one or two critical installations they might be worth using in spite of their drawbacks.

A firepot is made from an ordinary 55-gallon drum, equipped with a simple drip-feed or nozzle oil burner unit (Figure 2). Usually the drum is suspended from a tripod at the upstream end of a culvert, but it can be located anyplace that

2. A typical firepot installation at the entrance to a culvert. The firepot has made a thaw pit in the ice. The culvert entrance is out of sight in the thaw pit, and the fuel supply is beyond the thaw pit.

needs to be kept thawed. A gravity-feed fuel supply is placed nearby. If there is a significant amount of water flow and the firepot goes out, it will become flooded and frozen-in. And since the object is to prevent freezing of flow coming to the culvert, rather than just melting ice once it has formed, usually the fire is kept burning all the time. Oil consumption averages 25 to 30 gallons per day. A large fuel supply at the site may not be practical because of possible theft, so it becomes necessary to refuel every day or two.

Ditches. If a critical problem spot exists in a ditch, it is sometimes possible to use electric heating cables, steam thaw pipes (or portable steam lances), or firepots as described above. But usually the ice blockages in ditches are not confined to a few specific spots. Instead they exist over extended lengths of ditch, so some other remedy is called for.

An approach which involves some earthwork is to dig wider ditches, or to excavate basins at appropriate points in the ditch system. This provides storage space where ice can form without building up to levels that would reach pavements or other areas that must be kept clear. To size the storage space, flow rates must be estimated or measured. As a guide, a flow of 1 gallon per minute, when completely frozen, amounts to about 6500 cubic feet of ice in 30 days. This is equal to an acre of ice about 1.8 in. deep. Ordinarily, the

spring thaw will take care of melting-out the stored ice, but it might be necessary to thaw the culverts in the drainage system.

Another approach to solving ditch ice problems is to install temporary covers over the ditches. The covers provide dead air space as insulation so that the ditch flow is protected from freezing. Usually this would be done only at the points where the flow is most likely to freeze: shallow spots, flat points in the ditch slope, or parts of ditches that are unprotected by overhanging vegetation. The covers may be made of plywood, sheathing, corrugated metal or fiberglass, rigid plastic foam, or any sort of panel material. Since the ditch probably would be too wide for the cover pieces to span it, posts set in a grid pattern are needed for support. On top of the cover, insulation material can be added (for example, brush, sawdust, straw, or simply snow) to a thickness of a foot or two. Natural snowfall will add to the insulating properties of the cover.

Covers are expensive and time-consuming. They have to be installed in the fall and removed in the spring before meltwater runoff begins. But they can be very effective, and may be worth considering for critical problem spots.

Subsurface drain outlets. Frozen and blocked outlets for subsurface drains can be prevented in many cases by heating or insulating against natural heat loss. Since the water temperature in a subsurface drain system is usually several degrees higher than surface flow in the winter, insulating the drain outlets has a good chance of working well. This is done in the same way as providing insulating covers for ditches. The cover begins at the outlet and goes downstream as far as necessary, to a point on the outlet channel where ice formation either will not happen or would not matter if it did.

In relatively mild climates, another way of stopping heat loss from drain outlets is simply to hang canvas or burlap over the outlet. This cuts down on the cold air entering the drain, and yet the flow can seep past the fabric without freezing.

Heating of drain outlets, either with electric heating cables or steam pipes, is done just the same as for culverts.

Ground seepage. Sometimes maintenance personnel are faced with the problem of ground seepage, instead of concentrated flow, leading to troublesome ice buildups. The seepage may come from rock faces, cut slopes, natural slopes, or other

3. An ice fence installation, which is holding back ice formed by seepage from the slope at right.

places. Very large ice masses can form from small seepages, and the problem comes when these ice masses grow to the point where they encroach on the road or other area that has to be kept open.

These ice buildups can be held in place, away from the pavement, by temporary barriers. In Alaska, these are known as ice fences (Figure 3). They are made of snow fencing or wire fencing, and are faced with plastic sheeting, tar paper, canvas, burlap, etc. These fences do not need to be very strong, because they hold back only a thin layer of water at any one time before the layer freezes. The temporary barrier is removed just before or shortly after melting begins in the spring.

Design changes

Often the solution to an ice blockage problem lies in changes in design. Of course this is out of the hands of personnel concerned with maintenance, but still they can be alert to a few possible design changes, and make recommendations for changes when needed.

Certainly the most obvious design solution for ice blockage problems is to provide more and larger drainage structures. Culverts with larger vertical dimensions, or small bridges instead of culverts, will allow more ice to form before they be-

4. A staggered culvert installation. The upper culvert at right can carry flow when the lower culvert is blocked by ice.

come blocked. This is likely to provide openings that are larger than those for the design storm or the design flood. Providing more drainage facilities than otherwise might be needed stems from the idea that ice blockages will divert flow to spots that are normally dry. In this way the route or installation would be protected from unexpected washouts.

Another design solution is the use of staggered culverts. This means that two or more culverts are used for one stream, one at the ordinary location at the base of the fill, and another at a higher elevation in the fill (Figure 4). The higher culvert is usually dry except during the spring, when it carries runoff while the lower culvert is blocked by ice. The lower culvert will be cleared of ice during the spring thaw, leaving the higher culvert dry again. This technique works only where the fill is deep enough to handle the higher pipe, and where there is enough room to store the ice that will form upstream when the lower culvert is blocked.

5. A specially constructed narrow, deep channel to carry low winter flows. The narrow channel is formed by rock-filled wire gabions.

Some ice problems in ditches and small streams can be solved by modifying the channel. This usually means deepening and straightening the channel, and perhaps even making a very narrow and deep channel for low winter flows (Figure 5). The channel is usually deepened at riffles or rapids, because the ice blockages often get started at these shallow areas. Deepened channels let an ordinary ice cover form, and yet provide adequate space under the ice cover to carry the flow.

Additional information

Four CRREL publications (listed below) provide useful additional information. These reports apply to icing in cold climates, and they also contain ideas that are applicable to the problems of ice-blocked drainage in milder climates.

Carey, K.L. (1970) Icing occurrence, control and prevention: An annotated bibliography. USA Cold Regions Research and Engineering Laboratory Special Report 151. AD 711534.
Carey, K.L. (1973) Icings developed from surface water and ground water. USA Cold Regions Research and Engineering Laboratory Monograph III-D3. AD 765452.
Carey, K.L., R.W. Huck and D.A. Gaskin (1975) Prevention and control of culvert icing: Summary report on studies, FY 1966–70. USA Cold Regions Research and Engineering Laboratory Special Report 224. AD A010328.
Gaskin, D.A. and L.E. Stanley (1974) Application of electrical energy to culvert icing problems: A laboratory study. USA Cold Regions Research and Engineering Laboratory Technical Report 248. AD 777516.

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